DOCUMENT RESUME

ED 141 790 CS 003 575

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TITLE Knowledge Transfer in Learning from Texts.
INSTITUTION Rand Corp., Santa Monica, Calif.
REPORT NO P-5773
PUB DATE Feb 77
NOTE 20p.; Not available in hard copy due to marginal legibility of original document
AVAILABLE FROM Publications Department, The Rand Corporation, 1700 Main Street, Santa Monica, California 90406 ($1.50)

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS Cognitive Processes; Concept Formation; Critical Reading; Instructional Materials; *Knowledge Level; *Learning Processes; Literary Discrimination; *Memory; *Reading Comprehension; *Reading Research; Teaching Techniques; *Textbook Content

ABSTRACT

The process of acquiring knowledge from texts is considered from two perspectives: the learning of the individual facts in the text, and the integration of the facts into a coherent representation reflecting relations among the facts. The former process is presumed to depend on the linguistics content of the text, while the latter process depends primarily on the text structure or the manner in which the content is organized. The acquisition of information from a text can be influenced by alterations to either process. Repeating structure across successively presented texts facilitates memory for the later passages. This suggests that knowledge of text structure is used to guide encoding of specific facts. On the other hand, repeating some text content in passages with different structures produces interference in learning of the new content in later passages. The implications of these results for the selection of instructional strategies are discussed. (Author)

KNOWLEDGE TRANSFER IN LEARNING FROM TEXTS

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February 1977

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The Rand Paper Series

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Abstract

The process of acquiring knowledge from texts is considered from two perspectives: the learning of the individual facts in the text, and the integration of the facts into a coherent representation reflecting relations among the facts. The former process is presumed to depend on the linguistic content of the text, while the latter process depends primarily on the text structure, or the manner in which the content is organized. The acquisition of information from a text can be influenced by alterations to either process. Repeating structure across successively presented texts facilitates memory for the later passages. This suggests that knowledge of text structure is used to guide encoding of specific facts. On the other hand, repeating some text content in passages with different structures produces interference in learning of the new content in later passages. The implications of these results for the selection of instructional strategies are discussed.

The acquisition of knowledge through reading text is a common source of learning in an instructional setting. In a typical learning environment, a student must study texts containing information on related topics and situations and integrate that information into a coherent knowledge representation. As any educator knows, the knowledge actually acquired by a student in this situation is only a small subset of all to-be-learned information. The research reported in this paper investigates the influence of the structure of presented textual information on the learning of related information. In essence, the following question is addressed: When sets of topically related material containing shared knowledge are to be learned, how are they best presented to the learner? The motivation for this research has been to discover those techniques for organizing information that optimize learning.

Our approach to this instruction problem has been to manipulate experimentally what knowledge is available to a learner (the TRAINING material) and how well it is learned, and then observe how that knowledge influences the acquisition of new information (the TARGET material) that is related to the training material. This general method has a long history in experimental psychology, especially in paired-associate studies, and is referred to as the proaction paradigm. In the research reported here, we have tried to use as experimental stimuli meaningful texts in an attempt to approximate normal learning environments. This has necessitated the definition of more complex

relationships between training and target materials and a more complex characterization of what a subject has learned than is customary in tracitional verbal learning experiments.

For example, I have previously distinguished two types of knowledge in texts containing event sequences: content and narrative structure (Thorndyke, 1977). Narrative structure can be thought of as a syntactic structure for describing well-formed stories. It expresses text-level knowledge about the organization of events in the passage: the setting of the passage, the goal of the main character in the passage, the events comprising attempts of the main character to achieve the goal, and the resolution of the initial problem. The rules for the organization of events into a problem-solving sequence can be expressed independently of the particular selection of characters, goals, or particular actions. That is, the situation-event contingencies that characterize the organization of events into episodes and episodes into plots provide a grammatical description of stories, just as a linguistic deep-structure representation characterizes intra-sentential relationships. A story encoded according to this structural analysis is represented as a hierarchy with intermediate nodes corresponding to abstract structural elements of the plot organization and terminal nodes corresponding to actual propositions from the story. Text content, on the other hand, expresses knowledge at the level of individual sentences. The content of a sentence is represented by both a syntactic

structure and a semantic structure. The semantic structure consists of a relation, or predicate, and its arguments, or details. This distinction between text structure and content has been noted elsewhere in discussions of text "macro-structure" and "micro-structure" (van Dijk and Kintsch, 1977). Research in cognitive psychology has recently investigated the memory representation of both text structure (Rumelhart, 1975; Thorndyke, 1977; Mandler and Johnson, 1977) and text content (Kintsch, 1974; Meyer, 1975; Frederiksen, 1975). These distinctions will be useful below in characterizing the kind of information a learner acquires from a text.

When a person reads a text, the knowledge that he extracts from it includes not only the individual facts, but the relationships among the facts. This latter knowledge permits him to integrate all the information from the text into a representation in memory that is not merely a concatenation of sentences. Rather, the memory representation will reflect the organization of sets of sentences into higher-order functional elements that compose well-formed texts. Thus learning from text is assumed to require the acquisition of individual facts and the combination and integration of these facts into higher-order text structures. If this is true one ought to be able to improve learning of a text either by facilitating the learning of individual facts or by simplifying the the integration process. Methods for accomplishing both goals are proposed and examined below. The latter technique is considered first.

Transfer of Structure

In one experiment (Thorndyke, 1977), subjects were presented for 90 seconds a narrative passage of approximately 200 words to study and learn. The text was a narrative account of a hypothetical island on which the inhabitants tried to win senate approval for the construction of a canal. Following this story, subjects were presented a second story of the same length to read and remember. After a short delay, subjects were asked to recall the entire second story. The second story bore one of three relationships to the first story. In the REPEATED STRUCTURE condition, the second story had a narrative structure identical to the first story but entirely different content. In this condition, the second story was about a farmer whose animals were trying to convince him to build a new barn. The role of the events of the story in the problem-solving framework were identical to those of the first story, but the topic, characters, and particular actions were completely unrelated in the two stories. Thus a single representation of a narrative structure, formulated according to a grammar of plot organizations (Thorndyke, 1977), was used to produce two stories with unrelated details. In the REPEATED CONTENT condition, the second story repeated some of the semantic content of the first story in a new narrative framework. That is, the second story was about the farmers and senators of the island engaged in a new, unrelated series of episodes. In this condition, then, the representations of narrative structure were different for the two stories, but

the characters in the stories were the same. In the UNRELATED condition, the second story shared neither content nor narrative structure with the first story. Hence, this story served as a control condition against which to measure the transfer effects of structure and content.

Across all subjects, the mean free recall for the facts of the UNRELATED second story was 51%. However, in the REPEATED STRUCTURE condition subjects' recall improved by 22% over the control condition. On the other hand, recall of the REPEATED CONTENT story was decreased by 28% relative to the control story. These results were interpreted as evidence for the use by subjects of organizing frameworks for integrating the facts of a text. In the REPEATED STRUCTURE condition, subjects learned during Story 1 presentation a structure for encoding the story events into a well-formed narrative description. This structure consisted of a hierarchy of abstract conceptual relationships among characters, goals, and event sequences for attaining these goals. When the second story was presented, subjects could use the same framework encoded for Story 1 to encode at the terminal nodes of the hierarchy the new characters and events of Story 2. Hence the task of learning the new facts was simplified by the prior learning of the integrating structure.

Other experiments (Thorndyke, 1977; Experiments I and II) have confirmed that learning an organizing framework affects the ability to learn individual facts in a text. When the same text

content was presented in a variety of meaningful structural forms, comprehensibility and subsequent recall of the text were found to be a montonically increasing function of the structural similarity between the text and a well-formed goal-directed narrative (as defined by the grammar). That is, the ease of learning a fact appears to be dependent on the context or structure in which that fact is presented, as well as how well that structure is previously learned.

However, in the REPEATED CONTENT condition the transferred information comprised particular predicates of the setting; namely, location and character information. But in Story 2 the characters previously learned were assigned to different roles and relationships than in Story 1. So the benefits for learning Story 2 of transferring some detailed information (the character names and location of the events) were outweighed by the interfering effects of having integrated those facts in a way inappropriate for learning Story 2. Thus net interference was observed for Story 2 learning in the REPEATED CONTENT condition relative to the UNRELATED condition.

Transfer of Content

It is often the case that a student must learn several facts with the same general form. In this case it may be desirable to facilitate learning of the individual facts that share the common form. The constraints on the learning of several facts with

similar content were examined in another series of experiments, in which transfer effects of structure were tested at the level of individual facts within a text. In this study a subject was required to learn facts that shared common predicates and topics but differed in detailed knowledge, a situation commonly faced by a learner. For example, one might want to teach the following information about Mount Rushmore:

> "Mount Rushmore has four figures represented on it. George Washington was the first President and lived at Mount Vernon. Thomas Jefferson was the third President and lived at Monticello. Abe Lincoln was the 16th President and lived in a log cabin. Theodore Roosevelt was the 26th President and lived at Sagamore Hill."

One way to conceptualize the knowledge contained in this description is to note that "Person i was the nth President and lived at location l" is a predicate repeated four times with different details each time. The repetition of predicate forms across the four sentences might be expected to facilitate learning of the presented information, since the knowledge of the predicates could be used to encode new details in already existing predicate structures. As predicate structures are repeated, their strengh in memory should increase. Thus as learning progresses, acquisition of new facts should be facilitated by increasing memory strength of the semantic predicate.

In addition, however, changing some details across occurrences of the predicates should produce competition for associations between the changed details and the predicates. As

each new fact is learned the number of details associated with a predicate increases, thus producing interference among the set of learned details. Such interfering effects should have a negative effect on learning. Therefore, as the number of repetitions of the shared structure is increased, there should be initial facilitation of learning (due to predicate repetition) followed by interference in learning (due to competition for associations) (Hayes-Roth, 1977).

In an experiment designed to test these hypotheses (Thorndyke, 1976), subjects were presented n passages in succession (n=1,2,3,4, or 8) that were different examples of the same general concept (e.g., passages about n different constellations), followed by a target passage for study and recall. Each sentence in the target passages had a corresponding sentence at the same serial position in all n training passages that bore a particular relationship to it. For example, suppose sentence 5 of the target passage was "This constellation was originally charted at Palomar Observatory". Then sentence 5 of all preceding constellation passages was one of three types. In the REPEATED condition, the entire sentence (predicate and detail) was repeated intact: (i.e., "This constellation was originally charted at Palomar Observatory"). In the CHANGED condition, the predicate was identical but the detail was changed for each of the n passages (e.g.,"This constellation was originally charted at Mount Wilson Observatory" might be one of the n such prior sentences). In the UNRELATED condition, there

was no similarity between the target sentence and the corresponding training sentences (e.g., "This constellation is part of a gaseous nebula" might be one such sentence.)

The relationship of interest was how recall of a fact, both predicate and detail, would be influenced by the type of information transferred among passages about that fact and the number of prior exposures to the information. The results are shown in Figure 1. The "0" point on the abscissa is the mean of all target sentences in the UNRELATED condition. Note that for the REPEATED sentences, recall of both predicates and details increased with number of presentations, demonstrating the well-known effect of repetitions on learning. Similarly, recall of the constant predicate in the CHANGED condition (i.e., "This constellation was originally charted somewhere") increased over number of presentations, even though the detail associated with the predicate varied across passages. Thus the practice effect obtained for the REPEATED sentences was also obtained for the repeated portion of the CHANGED sentences. Such selective facilitation of predicate learning has also been demonstrated in a retroaction paradigm (Bower, 1974).

On the other hand, recall of the CHANGED detail, that part of the sentence that varied across texts, was initially facilitated, then interfered with, and finally reached asymptote. Thus prior training on the CHANGED predicates strengthened their

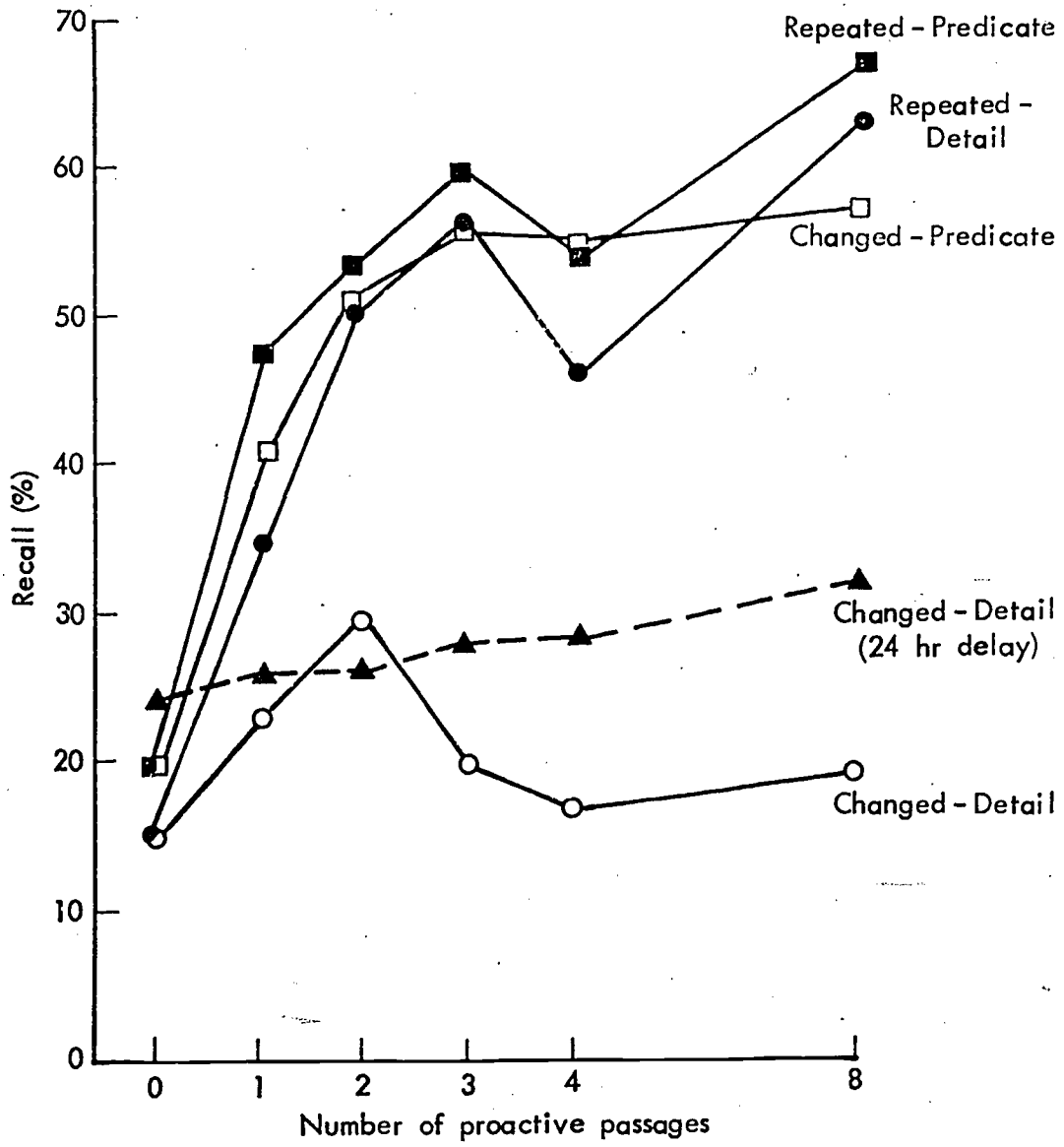

Fig. 1 — Free recall of facts from a text as a function of type and frequency of prior knowledge presented about the facts

memory representation and facilitated learning of the associated details until the interfering effects of competing associations produced decrements in recall of the details. This inverted U-shaped function demonstrating the combined effects of facilitation and interference during learning has been demonstrated with other types of experimental materials as well (Hayes-Roth, 1977a).

In another experimental condition, it was found that delaying the presentation of the target passage for 24 hours after the training sequence produced no differences in recall of CHANGED details across number of prior proactive passages. That is, when training materials preceded the target materials by a long time interval, the degree of learning was independent of the number of prior presentations of the shared predicate. This result is shown by the dashed lines in Figure 1. Furthermore, for a given number of prior presentations of a predicate, less interference was produced by a 24-hour interval between training and target presentations than by immediately following the training material with the target material. The superiority of recall in the delay condition suggests that interference due to competing associations among related items can be eliminated completely by reducing the confusability between the training materials and the related to-be-recalled target material.

Conclusions

The results presented here on the influential nature of structural contexts on the learning of facts contained in the contexts may have important implications for the design of instructional texts and techniques. Some of these implications are described below in the context of the experimental results reported here.

(1) Knowledge of the structure of material can facilitate learning of the material. That is, knowing in advance the context in which a fact will occur and the relevance of the fact will facilitate learning the fact. This suggests that effective teaching materials and procedures might emphasize the organizational and structural characteristics of the to-be-learned material. One might, for example, teach a subject domain in a top-down hierarchical fashion, by making explicit during initial exposures the general form or structural characteristics of the material to be presented, and gradually increasing the degree of detail and specificity. Thus initial learning would consist of acquisition of the appropriate general structure, while subsequent learning would require the acquisition of detailed facts to fill out the overall organizational framework. This presentation strategy has been termed "web teaching" (Norman, 1973). This instructional strategy might be implemented as both organizational and spatial phenomena: material organized in a structure-sensitive manner might be presented with visual cues such as spatial organization and segmentation. Such a method would exploit the power of mental

imagery as a storage and retrieval aid as well as utilizing optimal organizational characteristics. The use of structural information as an advanced organizer has been proposed elsewhere (Ausubel, 1963; Mayer and Greeno, 1972) and has been occasionally implemented with some success (Ward and Davis, 1939).

(2) Making available to a learner facts that can be substituted for a to-be-learned fact interferes with learning. Such substitutions can consist of either new relationships among previously learned concepts or details that share the same semantic predicate. Conversely, however, this interference can be minimized by instructional techniques that highlight the differences between the potentially confused facts. Such techniques might include a) spacing the learning of the related facts over time, or b) changing the surface features of the related information by embedding it in varying syntactic forms (Hayes-Roth, 1977b). Both techniques appear to permit shared structures to be learned and transferred to new contexts advantageously while particular contexts remain differentiated.

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Acknowledgements

This research reported here was partially supported by Contract No. DAHC15-73-0181 from the Defense Advanced Projects Research Agency of the Department of Defense.